10/019868
531 Rec'd PCT/ 23 DEC 2001
ENGLISH TRANSLATION
01PH 0406USP

Phoenix Contact GmbH &Co 3/PRTS

Method for quasi-continuous transmission of a temporally variable parameter

The invention relates to a method for quasi-continuous transmission of a temporally variable parameter between a transmitting and a receiving device, and a control and data transmission system to carry out the method.

Current control and data transmission systems are used in a variety of ways for automation technology. Information is transmitted from a transmitter via a transmission medium, for example a data bus, to one or more receivers. If the temporal value of a parameter changes, the need often arises to transfer the temporally varying values of the parameter to the receiver. Since the data line is designed in many cases for the communication of a plurality of bus components, continuous data transmission between the transmitter and receiver is not generally possible, wherefore the data communication must be carried out by means of the transmission of discrete values. However, the consequence of this type of transmission, for example via an automation bus such as the field bus, is that the temporally varying parameter is present in the receiver in the form of discrete values only, and continuous transmission of a continuously varying parameter often cannot be performed without blocking the communication of other bus components with a control unit and/or with other bus components. In the case of a temporally varying parameter which is transmitted via a transmission medium to a receiver, where it is intended to initiate an

operationally related function in response to its time characteristic, the problem therefore arises that no data occur between the transmission of two values of the parameters concerned. For example, a parameter is transmitted once per second so that it does not adversely affect the general data transfer too much, i.e. block the latter. The response of the system may be delayed accordingly on the grounds of the time-discrete transmission by a variable time δt, the maximum value of which is determined by the time difference between two transmissions, i.e. is 1 second.

Furthermore, it may also be necessary, in particular for control tasks, for a sensor signal to be supplied as a control parameter with a substantially higher update rate to a controller input. However, this cannot usually be provided in a conventional manner by means of a data channel used in control and data processing systems.

One solution can be provided by routing the parameter via a direct line to the receiver, rather than via the data channel, for example a bus. However, this conflicts with the general aims of interconnecting sensors and actuators involved in a control and data processing system via the bus and controlling the system centrally. Furthermore, a cable is required between the sensor and the receiver which, for example, results in high additional cabling outlay if a plurality of positioning devices are involved and runs counter to the concept of uniform data communications via the automation bus.

The object of the invention is therefore to eliminate the indicated disadvantages of the state of the art.

This is already achieved according to the invention by a method with the features of claim 1 and a control and data processing system to carry out the method with the features

of claim 13.

Information is advantageously transmitted in each case at discrete time intervals via the transmission medium between the transmitter and the receiver and, in a processing device connected downstream of the receiver device, the information is used for at least approximate calculation of the time characteristic of the parameter. In a surprisingly simple manner, at least approximate values are thus obtained for each time by utilizing one of the inventive ideas of the invention, i.e. by transmitting discrete values and by approximating or determining the time characteristic of the parameter during the period between two transmissions. A typical threshold value switch or limit value switch can thus be supplied without interruption with an input signal, with no need for a separate connection to the sensor. The "determine the time characteristic of the parameter" or "determine the time when the parameter attains or exceeds a predefined value" processes are to be regarded here according to the invention as identical. It lies within the scope of the invention to transmit an individual value or a plurality of values simultaneously in an individual transmission. Furthermore, the time intervals between individual transmissions do not necessarily have to be equidistant.

If the information transmitted via the transmission medium is in each case at least one discrete value of the temporally variable parameter itself, the time characteristic of the parameter can thus be calculated in the processing device following the transmission of at least two values.

The entire multiplicity of essentially known methods, for example linear interpolation, polynomial interpolation or spline interpolation, can be used to approximate the time characteristic of the parameter under consideration. According to the invention, interpolation here designates the

calculation of values of the parameter which may also lie outside the known interpolation points. The optimum interpolation method can be selected according to the expected time characteristic. Furthermore, it is also advantageously possible for the interpolation method to be modified through time with the increase in transmitted and therefore known values of the parameter, in order to achieve greater accuracy. For example, following an initial period of linear interpolation, it is possible to switch over to interpolation with cubic splines. In this way, the method can also be adapted according to the characteristic of the temporally variable parameter.

If the parameter is in a known functional relationship with time, the characteristic of the parameter can also be directly determined in the processing device if, for example an initial value has been transmitted to the processing device.

Operationally related functions can thus be initiated without interruption in response to the calculated characteristic, or the calculated parameter can be used as a continuous input parameter for a control circuit. Here, the term "operationally related function" designates all actions which may play a part in connection with the operation of an installation or machine, for example control of an actuator, recording by a sensor, but also collection and storage of data, etc.

The idea of the invention can also be used if information which is in a specific and known relationship with the time characteristic of the parameter is transferred at discrete time intervals via the bus.

Furthermore, in order to allow for a time delay in the calculation and therefore a time delay in the calculated characteristic of the parameter in relation to the actual

characteristic, a time marker which essentially indicates the time of recording of the discrete value of the parameter, for example, can be transmitted simultaneously with the transmission of the discrete value of the parameter. The quantity of the transmission time which essentially causes the described delay can thus be determined and is compensated accordingly, so that ultimately the respective real-time characteristic of the parameter is available for further processing, corresponding to quasi-real-time transmission. The transmission of a time marker, for example to define a recording time, is particularly important for those systems which operate according to the collision procedure (e.g. CSMA/CD) for data transmission and therefore have no fixed bus transmission times. The individual bus transmission time for each individual transmission can thus be determined with the simultaneous transfer of the relevant time marker and can be taken into account in calculating the time characteristic of the parameter.

The method according to the invention can essentially be used in all known control and data transmission systems in which data are transferred via a common data line, but also quite generally in discrete transmissions between a transmitter and a receiver, if an action is to be initiated in a device connected downstream of the receiver in response to the time characteristic of a signal.

The invention is explained below by describing a number of embodiments, based on the attached drawings, in which:

Fig. 1 is a block diagram showing a section of a basic device for carrying out the method according to the invention,

Fig. 2 shows a first example of a temporally variable parameter (Fig. 2a) and its approximation according to the invention (Fig. 2b), and

Fig. 3 shows a second example of a temporally variable parameter (Fig. 3a) and its approximation (Fig. 3b).

Fig. 1 shows the principle of the invention. A temporally variable parameter $S = F(t)$ is recorded and transferred from a transmitting device 1 via a transmission medium or a transmission path 2 to a receiver device 3. This transfer is carried out at discrete time intervals, so that discrete values of the parameter S, i.e. $S(t_0)$, $S(t_1)$, $S(t_2)$, ... $S(t_n)$ occur at the receiver 3. A processing device 4, to which the received values are in each case forwarded, is connected downstream of the receiver 3. The time characteristic of the parameter $S(t)$ is approximated in this processing device 4 from the received discrete values by means of linear interpolation. The time characteristic, i.e. the value of the parameter under consideration at any given time, is thus available, or the time when the parameter attains a predefined value can be indicated. An operationally related function is initiated in response to the characteristic or the specified time.

The characteristic of a typical signal in a specific embodiment of the invention is shown in Fig. 2. Here, Fig. 2a represents the signal $S(t)$ of a sensor which measures the level of liquid in a container. The quantity of liquid in the container increases through time and is intended to be reduced by removing it from the container when a predefined limit G is attained. To do this, the container outlet is controlled at the predefined time. The components form part of a control and data transmission system, whereby the sensor is connected via a bus component 1 to the automation bus 2 (Fig. 1). The control of the container closure is connected via a further bus component 3 to the automation bus 2 and the central system controller. For

correct functional operation, the container closure controller requires the current level of liquid in the container at all times. However, due to the principle involved, discrete level conditions $S(t_0)$, $S(t_1)$, ... $S(t_n)$ are transmitted to the bus component of the closure controller at specific times t_0, t_1, ... t_n only. These discrete values are shown in Fig. 2a by dots indicating the relevant times on the curve at which the level conditions were recorded. In the present example, the temporal interval between the discrete values is 1 minute, so that the time to transmit the value via the serial field bus which is used is negligible, since the transmission times in systems of this type are typically within the millisecond range. The discrete values of the parameter $S(t_i)$ received by the receiver device via the automation bus together with the actual characteristic shown in Fig. 2b. According to the invention, a processing device 4 which determines an approximated time characteristic from the transferred discrete values of the level conditions is connected upstream of the controller 5 of the container closure 6. In the described example, linear interpolation is carried out for this purpose, but, depending on the embodiment of the invention, higher-order polynomial interpolation, for example, or spline interpolation is also possible. The choice of interpolation is determined by the expected characteristic of the parameter which is to be approximated. The data processing of the linear interpolation which is being performed in the processing device 4 includes the steps which are to be cyclically performed in order to determine the time characteristic of the level condition:

a) formation of the difference between the last two received values of the level condition

b) division of the difference calculated according to a) by the difference between the times at which the two values

were received,

c) multiplication of the result obtained according to b) by the time period elapsed since the time when the last level condition was received, and addition of the result to the last received level condition.

The values calculated in this way are shown on the continuous curve in Fig. 2b), which itself represents the actual characteristic, in the form of linear segments S_0, S_1, S_2, ... S_4. This approximation is carried out cyclically until a further discrete value of the level condition occurs, this level condition defining the instantaneous value, whereupon the described approximation is restarted. A special method ensures that the transition from the approximated to the newly received level condition, in contrast to the linear segment characteristic shown in Fig. 2b), does not run discontinuously. The level condition characteristic generated as described is fed as an input parameter to the container closure controller. During the calculation, the last-calculated value is in each case maintained constant as a controller input parameter by means of a special hold circuit, until a newly calculated value occurs. When the predefined level condition G is attained, the closure is opened. As shown in Fig. 2b, the calculated level condition shown by the corresponding linear segment S_3 attains the limit value G approximately at time t_x, at which the liquid container closure is then opened. Without approximation of the time function, the closure would not take place until time t_4, i.e. following the transfer of the subsequent discrete level condition and therefore too late.

In a different embodiment of the invention, the processing device does not calculate the time function, but, by means of linear interpolation, the time when the predefined limit level condition G is attained. This

calculation is performed in a similar manner to the calculation of the time function, and consequently requires no further explanation.

However, in other embodiments of the invention, the transmission time to transfer the discrete value of the parameter to the receiver device is not negligible. An example of this type is shown in Fig. 3. The curve shown in Fig. 3a describes the shift of a workpiece in one dimension by means of a drive, whereby the drive is intended to be de-activated on reaching a predefined position Y=G. Similar to the first example, the components form part of an automation system. The position sensor is connected via a bus component to a serial ring bus system according to EN 50254, via which data can be exchanged with the controller or via the controller with other bus components. The bus component allocated to the sensor transfers discrete positions $Y(t_1)$, $Y(t_2)$, ... $Y(t_n)$ at discrete time intervals to the receiver device, to which a processing device is connected. The transmission speed and the number of bus components determine a transmission period from one bus component to the other of around 2 milliseconds. In these observations, the transmission times from the sensor to the transmitter, or possible processing times, for example to provide a digital signal at the transmitting end, and also processing times at the receiving end are not taken into account, since they are generally negligible compared with the aforementioned bus transmission time. For the example of the positioning of an object, whereby the position is recorded with a sensor and transmitted via the bus with a bus cycle time of two milliseconds to a receiver and a downstream controller, which de-activates the drive on reaching a predefined position, this means that the object has been moved by a maximum of two millimeters too far if the drive moves the object at one

meter per second. However, high positioning inaccuracy of this type is unacceptable for most shift drives, for example for motherboard assembly.

Fig. 3b shows the time function calculated in the processing device on the curve designated by the letter A. Compared with the curve shown in Fig. 3a, which shows the actual characteristic of the position with the values Y_0, Y_1, … Y_5 recorded at times t_i, the described temporal delay corresponding to the bus transmission time t_a is evident.

According to the invention, this lag in the time function compared with the actual time characteristic of the position Y of the workpiece is compensated by taking account of the bus transmission time t_a when calculating the time function. In the case of linear interpolation, not only the time period which has elapsed since the time when the last value was received, but also bus transmission time t_a is also included as a multiplier. t_a is defined, for example, either by the simultaneous transmission of a time marker, with the aid of which the transmission time is defined through comparison with a time marker on reception, or by single measurement of the bus transmission time. The single definition is frequently adequate, particularly in the case of a serial field bus system according to EN 50254, since the bus cycle time is normally constant in a system of this type.

The time function calculated in this way is shown in the curve designated as B in Fig. 3b. The position signal Y applied to the drive controller thus corresponds at all times to the actual sensor signal (see Fig. 3a), resulting in the required accurate positioning of the workpiece.

In a further embodiment, in contrast to the last embodiment, a drive parameter rather than the position itself is transferred at discrete time intervals via the bus. The position of the object can be unambiguously calculated at all

times by means of this parameter. The determined relationship between the drive parameter and the position is stored in the processing device, for example in the form of an allocation table or a formula implemented by means of hardware or software. In the present example, this drive parameter is the power supplied to the drive. The displacement and therefore the position of the object can be determined via an allocation matrix stored in the processing device with a predefined supply duration of the predefined power, whereby the drive is set in such a way that it accelerates the object up to a predefined speed of 1 m/s and then maintains his speed.